of the same fact which also explains the prolongation of the cusps.

Finally, if we suppose that the convection clouds do not form a continuous sheet. but are distributed broadcast, with clear intervals for the descending partial currents which should accompany them, it becomes easy to believe that, under suitable circumstances and with sufficiently powerful optical means, it may sometimes be possible to penetrate the veil, and see at least some of the most salient features of the planet's actual surface. On the other hand, the underlying surface must react upon the clouds above, and it may well be that those sharply defined markings which have been recorded are nothing more than a result marked out upon the veil by the features hidden beneath.

The Eclipse of Hipparchus. By J. K. Fotheringham.

(*Communicated by* P. H. Cowell, M.A., F.R.S.)

In Cleomedes, *De Motu Circulari Corporum Cœlestium*, ii. 3, we find the passage:

Ὅλος ποτὲ ἐν Ἑλλησπόντῳ ἐκλείπων ἐτηρήθη ἐν Ἀλεξανδρείᾳ παρὰ τὸ πέμπτον τῆς ἰδίας ἐκλείπων διαμέτρου, ὅπερ ἐστὶ κατὰ τὴν φαντασίαν παρὰ δακτύλους δύο καὶ βραχύ.

The eclipse to which reference is here made is also mentioned by Pappus * in the following words:

ἐν γὰρ τῷ πρώτῳ περὶ μεγεθῶν καὶ ἀποστημάτων λαμβάνει [sc. Ἵππαρχος] φαινόμενον τοῦτο· ἔκλειψιν ἡλίου ἐν μὲν τοῖς περὶ τὸν Ἑλλήσποντον τόποις ὅλου τοῦ ἡλίου ἀκριβῶς γεγενημένην ὥστε μηδὲν αὐτοῦ παραφαίνεσθαι, ἐν Ἀλεξανδρείᾳ δὲ τῇ κατ' Αἴγυπτον τὰ δ μάλιστα πεμπτημόρια τῆς διαμέτρου ἐκλελοιπότα.

The latter passage is to be found, copied verbatim, in Theon.†

It is clear from these two passages that Hipparchus recorded a solar eclipse which was total at or near the Hellespont and was about four-fifths total at Alexandria. It is also clear from the context that Hipparchus used this eclipse in order to obtain the lunar parallax with a view to determining the distances and magnitudes of the Sun and Moon, and, as Dr. Hultsch observes, the values obtained were, like his value for precession, superior to the values afterwards obtained by Ptolemy, and were not surpassed by any modern astronomer before Halley.‡ In Cleomedes the computation is based upon the known distances of Alexandria and the Hellespont from Rhodes; as Rhodes was the home of Hipparchus, there is every reason to believe that these distances

* Quoted, with full *apparatus criticus*, by Hultsch, *Hipparchos über die Grösse und Entfernung der Sonne, Berichte der sächsischen Gesellschaft*, lii. (1900), *Phil.-hist. Classe*, pp. 169–200.

† *Ibid.* ‡ *Ibid.*

are derived from him, and that, in spite of the vagueness of the phrase ἐν τοῖς περὶ τὸν Ἑλλήσποντον τόποις, Hipparchus considered himself justified in treating the eclipse as total at the Hellespont itself. As Dr. Hultsch points out, the phrase ἐν τοῖς περὶ τὸν Ἑλλήσποντον τόποις is also to be found in Hipparchus' extant commentary on Aratus, where a particular duration for the longest day is said to hold good for that locality. This phrase in the passage quoted from Pappus is therefore in all probability derived from Hipparchus, and it would also appear that Hipparchus had obtained other information besides the record of the eclipse from the district of the Hellespont. The Hellespont, Rhodes, and Alexandria were regarded both by Hipparchus and by Ptolemy in the Almagest as situated on the same meridian, and it is therefore not improbable that Hipparchus had arranged to have observations made simultaneously at the three places, though, for the purpose of determining the lunar parallax, he only used the two extremes. The plural τοῖς τόποις may imply that Hipparchus had information from more than one place on the Hellespont.

This record, derived as it is from one of the greatest of ancient astronomers, giving the definite magnitude of a solar eclipse for two distinct places, has naturally received considerable attention. A full discussion of the eclipse, containing references to the work of previous astronomers, was contributed by Professor Celoria to the *Memorie della Classe di scienze fisiche, matematiche e naturali*, vol. vii., *Accademia dei Lincei, Seduta del* 7 *marzo* 1880, *Serie* 3. Professor Celoria, after an investigation of all possible eclipses from the time of Hipparchus backwards, identified this eclipse with that of Agathocles, − 309. Dr. Hultsch * afterwards proposed to identify it with the eclipse of − 128 November 20, an eclipse which Professor Celoria had discussed, but had rejected because, when computed with Hansen's values, this eclipse was not total anywhere near the Hellespont. Since then Professor Newcomb has discussed the eclipse in *Monthly Notices*, lxv. (1904), pp. 181–3, and Mr. Lynn in the *Journal of the British Astronomical Association*, xv., 1904–5, pp. 162–4. Professor Newcomb accepts Professor Celoria's identification, while Mr. Lynn, who has apparently overlooked the reference to Hipparchus, proposes the eclipse of + 29. It is rather curious that the eclipse of Hipparchus is nowhere mentioned in Professor Ginzel's *Spezieller Kanon der Finsternisse*.

I have little doubt that Dr. Hultsch's identification is correct. The date that he has selected falls in the midst of the astronomical activity of Hipparchus, and it is much easier to believe that Hipparchus compared observations made in his own time than that he happened to find observations made independently on his own meridian at an earlier date, and used them in default of observations of his own. Dr. Hultsch has not attempted to apply the eclipse to the correction of the lunar theory, and it is perhaps for this

* *Loc. cit.*

reason that his article has not received the attention that it deserves.

I have computed the eclipse of −128 November 20 with the following values:—

A. A set of lunar values, communicated to me by Professor Newcomb, embodying the result of a recent study of lunar observations from the Ptolemaic eclipses to the year 1908. In these values the secular sidereal acceleration of the Moon is fixed at 8″·012 a century, and no secular sidereal acceleration of the Sun is admitted.

B. A set of values in which the secular acceleration of the Moon is fixed 1″ higher than in Professor Newcomb's values, the other terms being identical with those in A.

C. A set of values in which the secular sidereal acceleration of the Sun is fixed at 1″, the other terms being identical with those in A.

D. Mr. Cowell's values, as given in *Monthly Notices*, lxvi. p. 525.

With these values I obtain, by means of Oppolzer's *Syzygientafeln*, the following elements of the eclipse:—

	Julian Day	G.M.T.	L′.	Z.	ε.	P.	Q.	log p.	log Δ L.	log q.	$u'a$.
		h m	°	°	°	°	°				
A.	1674630	1 19·5	236·074	−2·79	23·713	9·405	11·399	0·7001	9·7518	8·7498	0·5459
B.	,,	1 7·5	236·066	,,	,,	9·397	11·391	,,	,,	,,	,,
C.	,,	1 31·2	236·193	−2·78	,,	9·522	11·513	,,	,,	,,	0·5458
D.	,,	1 31·7	236·541	−2·75	,,	9·898	11·877	0·6999	9·7520	8·7501	0·5457

	log fa.	μ.	γ.	log n.	G.	K.	sin g.	sin k.	cos g.	cos k.	sin δ'.
		°			°	°					
A.	7·6774	20·56	+0·8153	9·7539	66·64	87·24	9n5559	9·9960	9·9698	9n1284	9n5233
B.	,,	17·57	+0·8147	,,	,,	,,	9n5560	,,	,,	9n1285	,,
C.	,,	23·44	+0·8252	,,	66·78	87·26	9n5562	9·9961	9·9699	9n1263	9n5240
D.	7·6775	23·47	+0·8570	9·7541	67·07	87·27	9n5571	,,	9·9697	9n1217	9n5257

	cos δ'.	N′.
A.	9·9743	98°·2
B.	,,	,,
C.	,,	,,
D.	9·9741	98°·1

From these elements I deduce the following magnitudes. The computation has in each case been made by Oppolzer's formula as given in his *Canon der Finsternisse*. In the case of Professor Newcomb's values I have made the computation for the middle of the Hellespont both by Oppolzer's formula and by Hansen's

formula as given in Oppolzer's *Canon der Finsternisse.* The results obtained by the two formulæ are identical:—

	West end of Hellespont.	Middle of Hellespont.	East end of Hellespont.	Alexandria.
	° ′	° ′	° ′	° ′
Latitude	40 1N.	40 8N.	40 22N.	31 11N.
Longitude	26 9E.	26 22E.	26 30E.	29 51E.
Magnitude:—				
A.	11·99	11·99	12·03	9·40
B.	Not computed.	Not computed.	Not computed.	9·70
C.	,,	,,	,,	8·87
D.	,,	10·81	,,	8·17

I have also computed the belt of totality as follows, by means of the formula given in Oppolzer's *Syzygientafeln* [53].

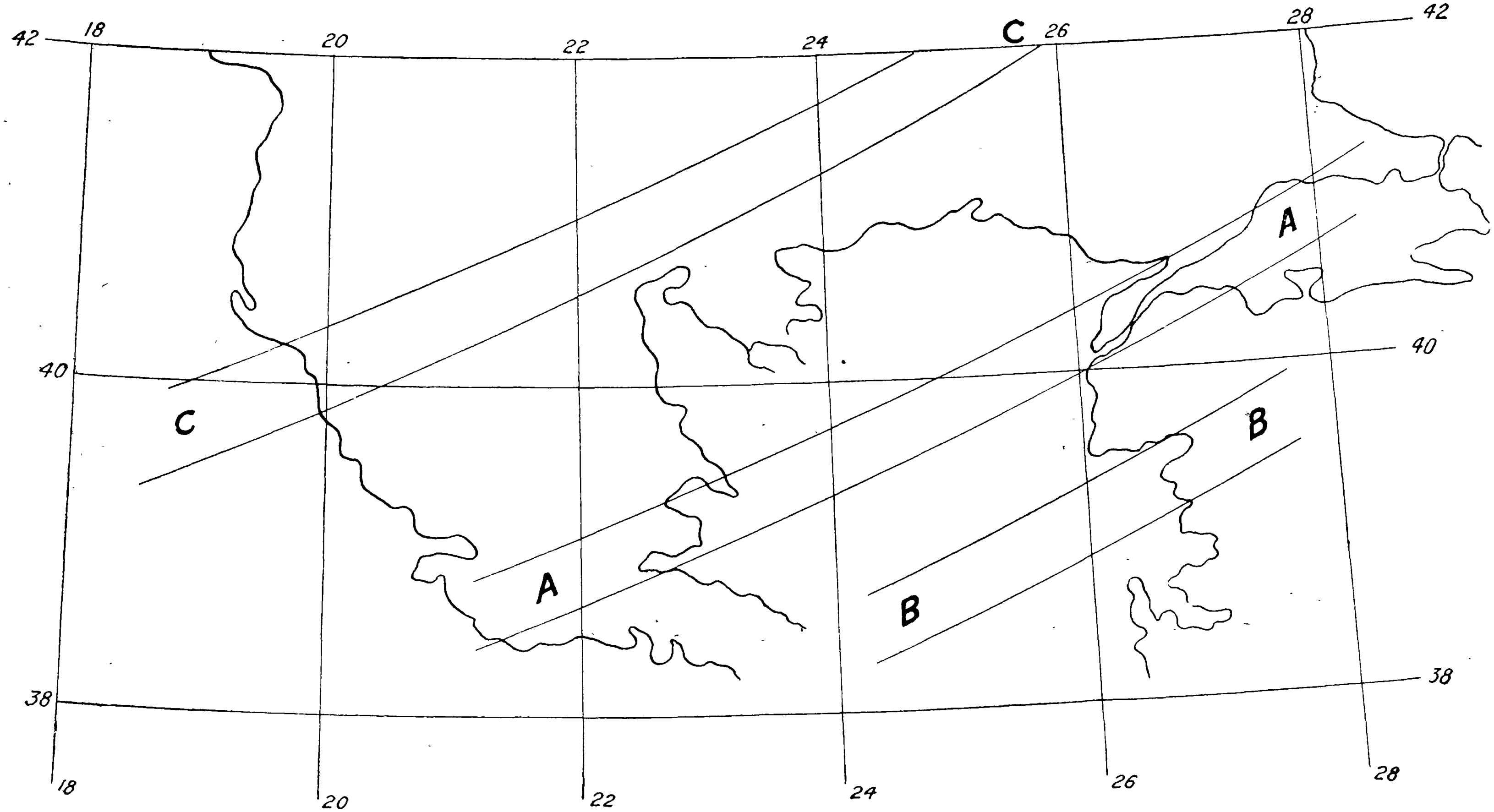
		Northern limit.			Southern limit.		
		$t=56°$	$t=60°$	$t=64°$	$t=56°$	$t=60°$	$t=64°$
		°	°	°	°	°	°
A.	Latitude	38·82	39·98	41·24	38·31	39·51	40·83
	Longitude	21·28	24·81	28·47	21·14	24·67	28·35
B.	Latitude	38·74	39·90	41·18	38·25	39·45	40·77
	Longitude	24·25	27·78	31·45	24·12	27·66	31·32
C.	Latitude	39·92	41·09	42·38	39·38	40·62	41·95
	Longitude	18·70	22·24	25·94	18·54	22·10	25·80
D.			Not computed.				

The accompanying map shows the belts of totality thus computed (p. 208).

It will be observed that the belt of totality is very narrow, measuring about 25 miles in width. This greatly lessens the range of values that will satisfy the record.

It will also be observed that Professor Newcomb's values make the belt of totality pass along the whole length of the Hellespont, while a very small alteration in the constants would remove the eclipse from the Hellespont altogether. As both sides of the Hellespont were studded with Greek cities, it is probable that the place or places of observation were in the immediate vicinity of that strait. Professor Newcomb's values also give a sufficiently accurate magnitude at Alexandria, 9·40 being very much nearer to four-fifths than to three-fourths, and being readily described as four-fifths. It will be observed that a small increase in the secular acceleration of the Moon would still satisfy the recorded magnitude at Alexandria.

Eclipse of Hipparchus. – 128 November 20.



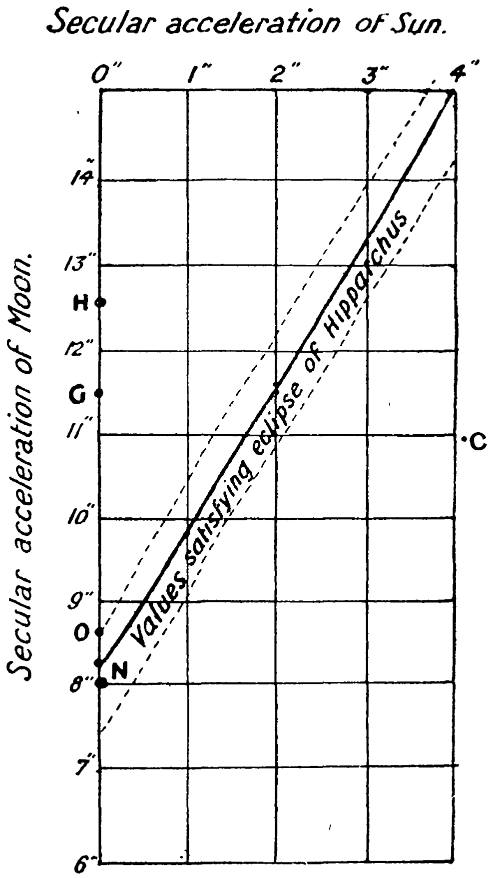
A A, zone of total eclipse computed with Newcomb's values.
B B, ,, ,, ,, secular acceleration of Moon 1″ in excess of Newcomb's value.
C C, ,, ,, ,, 1″ secular acceleration of Sun ; other terms from Newcomb.

The centre of Belt C is approximately 123 miles distant from the centre of Belt A, while the centre of Belt A is approximately 68 miles distant from the centre of Belt B. The distances of the belts of totality from each other are therefore in exact proportion to the differences in the magnitudes at Alexandria. As the addition of $1''$ to the secular acceleration of the Moon increases D (elongation of the Moon), but does not affect D–F (elongation of the node), while the addition of $1''$ to the secular acceleration of the Sun involves a corresponding diminution in D and an equal diminution in D–F, 55 miles out of the 123 between Belts A and C may be attributed to the alteration in D–F, the remainder being due to the alteration in D.

Belt B is at its nearest about 40 miles and Belt C is at its nearest 115 miles distant from the Hellespont. It follows, therefore, that a correction of about $+0''\cdot4$ or of $-0''\cdot1$ to Professor Newcomb's value for the secular acceleration of the Moon is the utmost that it is possible to apply without moving the belt of totality entirely away from the Hellespont. Similarly, $+0''\cdot1$ or $-0''\cdot2$ should be the greatest possible correction to the secular acceleration of the Sun. A further addition of $\pm n''$ to the secular acceleration of the Moon will still satisfy the eclipse, provided that it is counterbalanced by an addition of $\pm\frac{4}{7}n''$ to the secular acceleration of the Sun, where n is any quantity. By placing a liberal interpretation on the phrase ἐν τοῖς περὶ τὸν Ἑλλήσποντον τόποις so as to include all places within 20 miles of the Hellespont, we might increase or diminish the secular acceleration of the Moon by $0''\cdot3$, or that of the Sun by $0''\cdot2$. The effect of a correction in the Moon's perigee would be very slight compared with these corrections in the longitude of the Sun and Moon. An addition to the secular acceleration of the Moon's node, generally believed to be impossible, would increase D–F, but would not affect D; the effect of such an addition would be about three-fourths the effect of an equal addition to the secular acceleration of the Moon. It would appear, altogether, that if we do not revise the centennial motions, the eclipse can only be satisfied by a secular acceleration of the Moon amounting to $8''\cdot15 \pm 0''\cdot55 + n''$, accompanied by a secular acceleration of the Sun amounting to $\frac{4}{7}n''$.

Any correction in the centennial motions would involve a corresponding correction of one-nineteenth as much in order to satisfy the record of the eclipse. It is not likely that the resultant correction of the secular acceleration of the Moon would exceed $\pm 0''\cdot5$. Professor Newcomb's centennial motion of the Moon at the epoch 1800·0 exceeds Mr. Cowell's by $5''$, and the adoption of Mr. Cowell's value would involve a diminution of $0''\cdot25$ in the secular acceleration of the Moon. Similarly, Mr. Cowell's value for the centennial motion of the node exceeds Professor Newcomb's by $8''$; the adoption of this value would have to be counterbalanced by the addition of about $0''\cdot3$ to the secular acceleration of the Moon. The combined effect of these two corrections is practically nil.

The following diagram exhibits the different values which will satisfy this eclipse :—



C represents Mr. Cowell's values; G, Professor Ginzel's; H, Hansen's; N, Professor Newcomb's; and O, Oppolzer's.

The eclipse, therefore, affords a striking confirmation of Professor Newcomb's values, but is inconsistent with Professor Ginzel's and Mr. Cowell's. It remains to be seen whether this eclipse can be reconciled with those on which Mr. Cowell's and Professor Ginzel's corrections are respectively founded.

12 *Holywell, Oxford:*
1909 *January* 6.

Observations made during the partial Eclipse of the Sun on June 28, 1908, at the Royal Observatory, Greenwich.

(*Communicated by the Astronomer Royal.*)

Phenomenon.	Telescope.	Power.	Mean Solar Time of Observation.	Observer.
			h m s	
(*a*) First contact	Dollond (55 Ulundi Road, Westcombe Park)	...	5 13 36	A. C.
,, ,,	Merz Refractor	250	5 13 43·29	C. D
,, ,,	Great Equatorial (Corbett)	120	5 13 59·7	W. B.
(*b*) ,, ,,	Old Altazimuth	100	5 13 55·89	H. F.
,, ,,	Astrographic Equatorial	225	5 13 51·36	P. M.
,, ,,	Sheepshanks Equatorial	100	5 13 45·29	J. E.
(*a*) Last contact	Dollond	...	6 1 42	A. C.
,, ,,	Great Equatorial	670	6 1 41·08	B.
,, ,,	Merz Refractor	250	6 1 49·33	C. D.
,, ,,	Great Equatorial (Corbett)	120	6 1 49·46	W. B.
,, ,,	Old Altazimuth	100	6 1 52·27	H. F.
,, ,,	Astrographic Equatorial	225	6 1 34·53	P. M.
,, ,,	Sheepshanks Equatorial	100	6 1 52·37	J. E.

(*a*) Observations reduced to Royal Observatory, Greenwich, the corrections being $-1^s \cdot 38$ and $+2^s \cdot 03$ respectively; the result is given to the nearest second.

(*b*) Observation doubtful. Probably 5 seconds or more late.

The apertures of the telescopes used are as follows:—

Great Equatorial	28 inches
Merz Refractor	12¾ ,,
Astrographic Equatorial (guiding telescope)	10 ,,
Sheepshanks Equatorial	6¾ ,,
Great Equatorial (Corbett telescope)	6½ ,,
Old Altazimuth	4 ,,
Dollond	3 ,,

The initials A. C., B., C. D., W. B., H. F., P. M., J. E., are those of Mr. Crommelin, Mr. Bryant, Mr. Davidson, Mr. Bowyer, Mr. Furner, Mr. Melotte, and Mr. J. Evans, respectively.